Space Technology Research Grants

Multi-Fidelity Modeling and Simulation for the Analysis of Deployable Re-Entry Technologies Under Uncertainty

Completed Technology Project (2017 - 2021)

Project Introduction

The objective of the proposed research will be to identify and validate multi-fidelity modeling methods for the modeling and simulation of the flow field and thermal response of ADEPT and HIAD deployable re-entry technologies, and to implement these tools in the analysis and design of the two technologies under uncertainty. The proposed research will also compare the performance and reliability of ADEPT and the HIAD concepts for similar missions and corresponding re-entry trajectories subject to uncertainties in the operating (free-stream) conditions, geometry, and the physical modeling parameters. Due to the significant amount of aeroheating, re-entry system designs need to be robust and reliable. High-fidelity computational fluid dynamics and thermal response simulations can be computationally very expensive due to the complex physics seen at these flow regimes (turbulence modeling, non-equilibrium thermo-chemistry, radiation heat transfer, etc.) and may not be practical for direct use in the design and reliability assessment of re-entry technologies under uncertainty because of the large number of simulations required. The main idea behind multi-fidelity modeling is to combine a large number of data points from low and mid-fidelity models with a small number of data points from the high-fidelity models in a way that obtains a corrected model which maintains the accuracy of the high-fidelity model while reducing the computational cost. The key research components of the proposed project will include: (1) investigation of multi-fidelity approaches suitable for the problem, (2) integration of multi-fidelity modeling into an uncertainty quantification (UQ) framework, (3) comparison of the performance and reliability of HIAD and ADEPT configurations under uncertainty, and (4) investigation of multi-fidelity modeling for design optimization of deployable re-entry technologies under uncertainty. Component 1 includes an investigation into which low-, mid-, and high-fidelity computational tools should be used to create accurate multi-fidelity models for different output quantities of interest such as the surface pressure, shear, convective, and radiation heat flux. This component will also involve an investigation into the different types of multi-fidelity analysis including co-Kriging, polynomial chaos expansion, and support vector analysis. In component 2, the multi-fidelity modeling techniques will be integrated into a UQ framework in order to perform reliability analyses of ADEPT and HIAD configurations. In component 3, with multi-fidelity analysis and the UQ framework, a comparison of the performance and reliability of HIAD and ADEPT configurations will be done. The comparison will be made for similar missions subject to uncertainties in the operating conditions, geometry, and the physical modeling parameters in flow field and thermal response simulations. Finally, in component 4, an investigation into the use of multi-fidelity modeling for the design optimization of ADEPT or HIAD technologies under uncertainty will be performed. The multi-fidelity modeling approach will allow computationally efficient and accurate design of deployable re-entry technologies under uncertainty. The proposed research will focus on reducing computational cost while maintaining a high accuracy in modeling and simulation of robust and reliable re-entry

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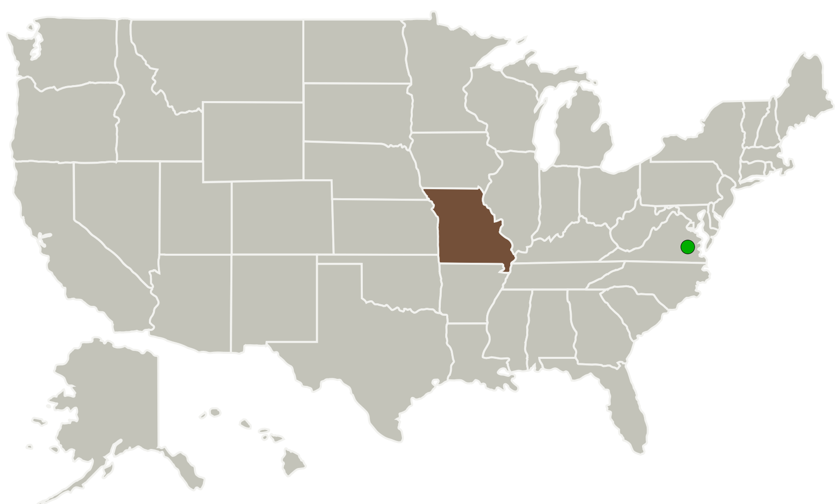
technologies with the consideration of uncertainty in the design process, and seek to demonstrate the use of multi-fidelity modeling for this purpose. The project will include strong collaboration with researchers from NASA Langley and ARCs. The results from the reliability analysis will be useful to NASA for the decision making process during the mission design phase. It is expected that the methodologies developed under this research can also be used to benefit the development of any present or future spacecraft technology that may be considered by NASA.

Anticipated Benefits

The results from the reliability analysis will be useful to NASA for the decision making process during the mission design phase. It is expected that the methodologies developed under this research can also be used to benefit the development of any present or future spacecraft technology that may be considered by NASA.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Missouri University of Science and Technology

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Serhat Hosder

Co-Investigator:

Mario J Santos

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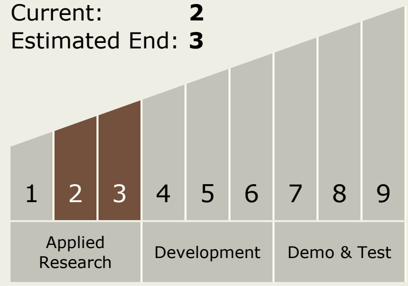
Organizations Performing Work	Role	Type	Location
Missouri University of Science and Technology	Lead Organization	Academia	Rolla, Missouri
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Primary U.S. Work Locations
Missouri

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.5 Modeling and Simulation for EDL

Target Destination

Foundational Knowledge